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EFFECT OF SULPHUR ON PRODUCTIVITY, ECONOMICS AND NUTRIENT UPTAKE IN SPINACH

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ABSTRACT

A field experiment was conducted during rabi season of 2009-10 and 2010-11 on a sandy loam soil at Raja Balwant Singh College, Bichpuri, Agra (U.P.) to study the effect of suphur levels (0, 15, 30, 45 and 60 kg S ha^{-1}) on productivity, profitability and uptake of nutrients by spinach (Spinach oleracea) crop. The results revealed that spinach crop responded significantly to sulphur application up to 45 kg S ha^{-1}. The sulphur application significantly increased spinach green foliage yield by 22.7, 67.0, 89.8 and 95.5 % at 15, 30, 45 and 60 kg S ha^{-1}, respectively over control. The highest dry matter yield (3.11t ha$^{-1)}$ was recorded with 60.kg S ha^{-1} which was slightly higher than that of 45 kg S ha-^{1} .The uptake of N, P, K and S by spinach crop increased with sulphur application to the soil but Zn uptake decreased at higher levels of sulphur. The protein content and yield of spinach increased significantly with sulphur application over control.The maximum gross returns, net returns (₹.40547 ha^{-1}) and benefit: cost ratios (176) were obtained with 60 kg S ha^{-1}. The S – use efficiency and apparent S recovery decreased at higher levels of sulphur.

Keywords: Sulphur, nutrient uptake economics, yield, spinach.

INTRODUCTION

Spinach, a leafy vegetable, is an excellent source of vitamin K, vitamin A (in the form of carotenoids), manganese, folate, magnesium, iron, copper, vitamin B2, vitamin B6, vitamin E, calcium, potassium and vitamin C. It is a very good source of dietary fibre, phosphorus, vitamin B1, zinc, protein and choline. Additionally, spinach is a good source of omega-3 fatty acids, niacin, pantothenic acid and selenium. The yield of spinach is influenced by application of sulphur. To sustain high yield of spinach, the application of sulphur is required in optimum amount. Sulphur (S) has been recognized as the fourth important plant nutrient after nitrogen, phosphorus and potassium. It is gaining considerable importance in quality crop production in the context of Indian agriculture, particularly when there is more and more use of non sulphur containing fertilizers and lesser use of organic manures. Sulphur has been known for its role in the synthesis of carbohydrates, proteins, vitamins and flavor compounds. It plays an important role in the formation of S-containing amino acids like cystine (27% S), cysteine (26% S), methionine (21% S), which act as building blocks in the synthesis of proteins. It has a role to play in increasing chlorophyll formation and aiding photosynthesis (Marschner. 1986). Sulphur also plays a role in the activation of enzymes, nucleic acids and forms a part of biotin and thiamine.Removal of S by crops in India is about 1.26 million tonne (mt), whereas its replenishment through fertilizers is only about 0.76 mt (Tiwari and Gupta, 2006). Furthermore, the use efficiency of added S through external sources is also very low, being only 8-10% (Hegde and Murthy 2005). In recent years an increased frequency of sulphur deficiency has been observed in crops and sulphur may become a factor limiting yield and quality of crops. Different crops require a considerable amount of sulphur for proper growth and there was no recommendation of sulphur fertilizer for spinach crop. Therefore, keeping the above facts in view, a field study was conducted to study the sulphur response and to find out the optimum dose of S fertilizer in spinach.

MATERIALS AND METHODS

A field experiment was conducted during rabi season of 2009-10 and 2010-11 at R.B.S. College, Research Farm, Bichpuri, Agra. The experiment was laid out in randomized block design with three replications. There were five levesl of sulphur i.e. 0, 15, 30, 45 and 60 kg ha^{-1}. The soil of the experimental field was sandy loam in texture, alkaline in reaction (pH 7.8), EC (0.17 dS m^{-1}), low in organic carbon (3.1 g kg^{-1}), available N (145 kg ha^{-1}) available P (9.5 kg ha^{-1}), K (108 kg ha^{-1}) and S (8.5 mg kg^{-1}). The spinach crop was sown using 5 kg of seed ha^{-1} during the month of October in both the years. The sulphur treatments were applied before sowing as per treatments through elemental sulphur. As per recommendation, a uniform basal dose of 100 kg N, 60 kg P_2O_5 and 60 kg K_2O were applied at showing through urea, di ammonium phosphate and muriate

potash respectively. Entire dose of phosphorus and potassium and half dose of N were applied at the time of sowing and remaining half nitrogen was applied one month after sowing. Rest of the management practices were in accordance with the recommended package of practices for the crop. Green foliage yields was recorded at harvest. Random chopped samples of green foliage were sun dried and placed in the oven at 65° C for 72 hours to estimate dry matter percentage and then it was multiplied with respective green foliage yield to calculate dry matter yield. Plant samples were analyzed for N by Kjeldahl method. Phosphorus was determined in di acid digest by vanado molybdate yellow colour method, K by flame photometer, sulphur by turbidi metric method (Chesnin and Yien, 1951) and Zn on atomic absorptions pectrophotometer (Jackson 1973). The uptake of nutrients was calculated from the data on concentration of the given nutrient multiplied by yields. Sulphur use efficiency was computed with the formula given below:

Sulphur use efficiency (kg produce/kg S applied) = $(Y_1-Y_0)/Sa$, Where Y_1 = yield (kg ha^{-1}) in test treatment, Y_0= yield (kg ha^{-1}) in the control plot, Sa=Sulphur applied in test treatment (kg ha^{-1}), The apparent S recovery was worked out as follows:

Apparent S recovery (%) =

$$\frac{\text{Uptake in treated plot} - \text{Uptake in control plot}}{\text{Fertilizer dose}} \times 100$$

Economics of different treatments was worked out on the basis of input and output on the prevailing market price.

RESULTS AND DISCUSSION

Yield

The data (Table 1) indicated that the spinach mean yield in control plot was 8.53 t ha^{-1}. The mean green foliage yield increased from 8.53 to 16.20 t ha^{-1} and mean dry matter yield from 1.52 to 3.11 t ha^{-1} with application of different rates of sulphur application. On an average, the increase in mean spinach green foliage yield over control was 22.7, 67.0, 89.8 and 95.5% with 15, 30, 45 and 60 kg S ha^{-1}, respectively. The response of sulphur application of spinach was found significant upto 45 kg S ha^{-1} and increase with application of 60kg S ha^{-1} was statistically non-significant over 45 kg S ha^{-1}. The increased yield with S application might be due to increased availability, absorption and translocation of S nutrient by and in to the spinach plant, increased enzyme activity, photosynthesis, transport of sugars, protein synthesis and ultimately increased crop yield. Singh and Singh (2003), Sriramachandrasekhran (2009), Sriramachandrasekharan and Shukla (2010) Ali *et al.* (2013) and Verma *et al.* (2014) also observed significant effect of sulphur application in onion, Okra, radish and fababean, respectively.

Table 1: Effect of Sulphur levels on yields of spinach

Sulphur (kg ha^{-1})	Green foliage yield (t ha^{-1})			Yield response (%)	Dry matter yield (t ha^{-1})		
	2008-09	2009-10	Mean		2008-09	2009-10	Mean
0	8.82	8.25	8.53	-	1.55	1.49	1.52
15	10.50	10.44	10.47	22.7	1.82	1.81	1.81
30	14.58	13.90	14.24	67.0	2.80	2.67	2.73
45	16.65	15.73	16.19	89.8	3.11	2.93	3.02
60	17.17	16.20	16.68	95.5	3.20	3.03	3.11
CD (P=0.05)	1.14	0.96	0.95		0.28	0.22	0.24

Protein

Application of sulphur gradually increased the protein content and its yield in spinach crop (Table 3). The protein content in spinach leaves ranged from 4.7 to 5.3%. The results of the present investigation find support from Ali *et al.* (2013) who observed a significant increase in protein content of fababean up to 60 kg S ha^{-1}. The increase in protein content with S could be due to the fact that N is an integral part of protein and the protein of vegetable crop contains relatively large quantity of S containing amino acids. The increase in protein yield in spinach due to S application was from 71.4 kg ha^{-1} in control to 164.8kg ha^{-1} with 60 kg S ha^{-1}. The results indicated a beneficial effect of S on protein percentage in spinach crop. Protein yield is a function of protein content and dry matter yield of spinach leaves and both the parameters increased with sulphur application thus resulting in a significant increase in protein yield. Omprakash et al. (1997) and Ali *et al.* (2013) observed that the protein yield of spinach crop was significantly increased with S application.

Nutrient uptake

The nitrogen uptake by spinach leaves increased significantly with increasing levels of sulphur (Table 2) over control. The increases in N

uptake by spinach leaves increased from 11.7 kg ha^{-1} at control to 26.0 kg ha^{-1} with 60 kg S ha^{-1}. The higher values of N uptake with S addition could be attributed to enhanced vigour of crop growth with increased N utilization and translocation into the plant resulting in the enhancement of the yield. Similar results were reported by Singh and Singh (2003) and Ali *et al.* (2013). The data (Table 2) indicate that the application of S significantly increased the phosphorus uptake in spinach from 3.8 kg ha^{-1} in control to 9.9 kg ha^{-1} at 60 kg S ha^{-1}. The changes in P uptake brought about by sulphur fertilization were pronounced and significant in spinach crop. These results are in agreement with the findings of Singh and Singh (2003).

Table 2: Effect of sulphur levels on uptake of N, P, K, S (kg ha^{-1}) and Zn (g ha^{-1}) by spinach

Sulphur (kg ha^{-1})	Nitrogen	P	K	S	Zn	Apparent S recovery (%)	S use efficiency (kg produce/kg S)
0	11.7	3.8	12.3	9.7	102.0	-	-
15	14.3	5.1	15.3	12.8	105.1	20.6	129.0
30	22.1	8.2	23.6	20.8	104.0	37.6	190.0
45	25.0	9.6	26.3	24.7	100.0	33.3	170.2
60	26.0	9.9	27.7	26.1	96.4	278	135.8
CD (P=0.05)	2.41	1.27	1.21	1.78	5.57	-	-

A progressive increase in sulphur levels gradually increased the uptake of potassium by spinach crop. Highest uptake of potassium was recorded with 60 kg S ha^{-1}, which might be due to higher yield of spinach crop. In the crop, the uptake of potassium under 15, 30, 45 and 60 kg S ha^{-1} was significantly more than the control. Similar results were obtained by Singh and Singh (2003) and Ali *et al.* (2013). Application of sulphur significantly increased the S uptake upto 60 kg S ha^{-1} by spinach crop (Table 2). The increased S uptake following sulphur application might have been contributed by increased sulphur concentration and yield of the crop (Singh and Singh, 2003). The minimum value of Zn uptake in spinach crop was recorded with 60 kg S ha^{-1}. Thus, the results indicate an antagonistic effect of S on Zn utilization by the crop. Ali *et al.* (2013) reported similar results.

Table 3: Effect of Sulphur on quality and economics of spinach

Sulphur (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Gross returns (₹.ha^{-1})	Net returns (₹.ha^{-1})	B:C ratio
0	4.7	71.4	34120	8990	0.35
15	4.9	88.6	41880	16735	0.66
30	5.1	139.2	56960	31800	1.26
45	5.2	157.0	64760	36976	1.46
60	5.3	164.8	66720	40547	1.76
CD (P=0.05)	0.09	12.5			

Economics

The data (Table 3) indicate that the highest gross profit (₹. 66720 ha^{-1}) and net returns (₹.40547 ha^{-1}) were obtained from 60 kg S ha^{-1} in spinach. The 45 kg S ha^{-1} proved as second best fetching the net returns of ₹. 36947 ha^{-1}. In the light of this, it can be argued that more green foliage (leaves) production with 60 kg S ha^{-1} may be the reason for the resultant profits. The income per rupee spent (B/C ratio) was highest (1.76) with 60 kg S ha^{-1} from the spinach. It is due to more net profit than cost of cultivation involved with this treatment. The second best treatment was 45 kg S ha^{-1} followed by 30 kg S ha^{-1}. The B/C ratio was minimum due to no sulphur application (control).

Efficiency indices

Apparent recovery (%) of sulphur was influenced by S levels with maximum recovery being at 30 kg S ha^{-1} (Table 2). Reduction in apparent recovery of S by spinach was noted at 45 and 60 kg S ha^{-1}. The range of apparent recovery by spinach was from 20.6 to 37.6 %. The response in kg produce/kg sulphur showed an increase upto the level of 30 kg S ha^{-1}. Further increase in the level of sulphur (45 and 60 kg S ha^{-1}) tended to decrease the sulphur use efficiency over 30 kg S ha^{-1}. Better S use efficiency was obtained with S addition upto 30 kg S ha^{-1} recording 190 kg green foliage of spinach/kg sulphur applied., in spinach crop. Similar increase in SUE with increasing levels of S application was reported by Ali *et al.* (2013).

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